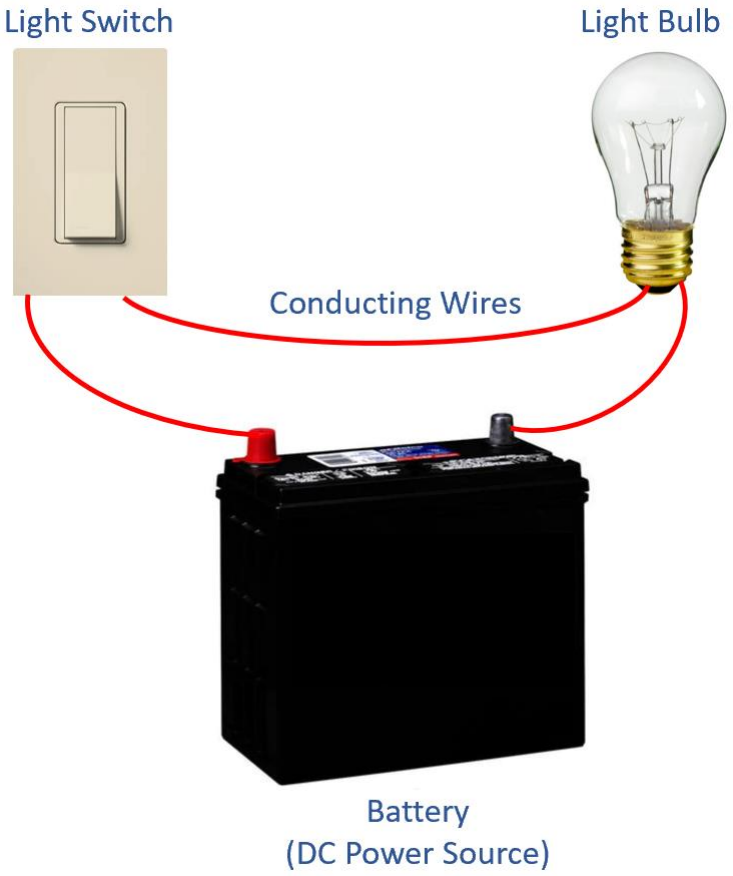
M2: Electrical & Motor Basics



Created by Tom Wylie, 6/8/22

Electrical & Motor Basics

After viewing this document, the student should be able to:

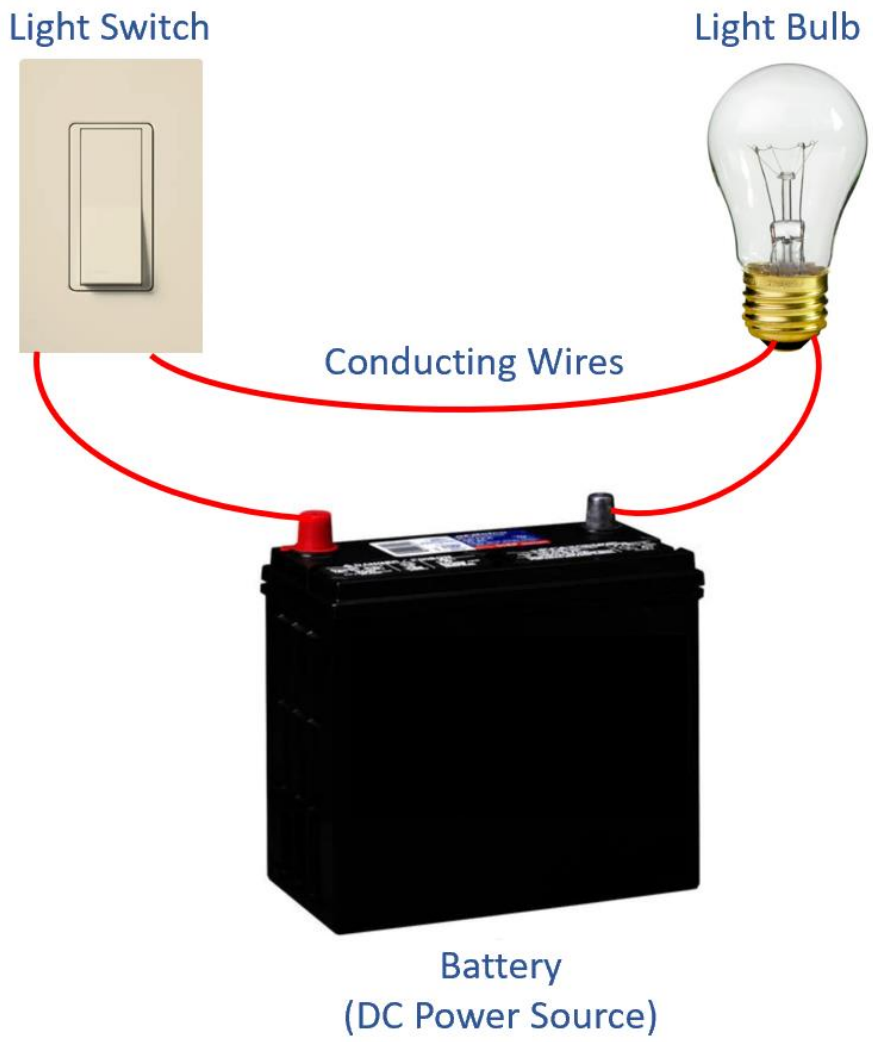
1. Determine what scale the dial should be set for on a digital multi-meter for a specific test.
2. Explain the different AC and DC voltage sources
3. Test a solenoid coil with a digital multi-meter, while out of circuit.
4. Test a N.O. and N.C. pushbutton with a digital multi-meter, while out of circuit.
5. Measure the resistance of N.O. and N.C. pushbutton and relay contacts
6. Explain the basic operation of an electro-mechanical relay.
7. Explain how a N.O. and N.C. relay contact operates in a relay circuit
8. Explain what a Start/Stop hold-in circuit is in relay logic.
9. Check the continuity of an open and a closed switch, using an ohmmeter
10. x

Course Disclaimer - Please Read:

This document is to overview the basics of electricity for the South Arkansas Community College students that are enrolled in the Intro to Technology course.

The intent of teaching electrical basics in the Intro to Technology course is to introduce the students to how electricity is used in a process and manufacturing environment. This course only introduces the students to the basic concepts and should not be used to replace a full electricity course.

Electrical Basics I



A typical electric circuit is made up of **4 parts:**

The **power source**, in this case is a battery.

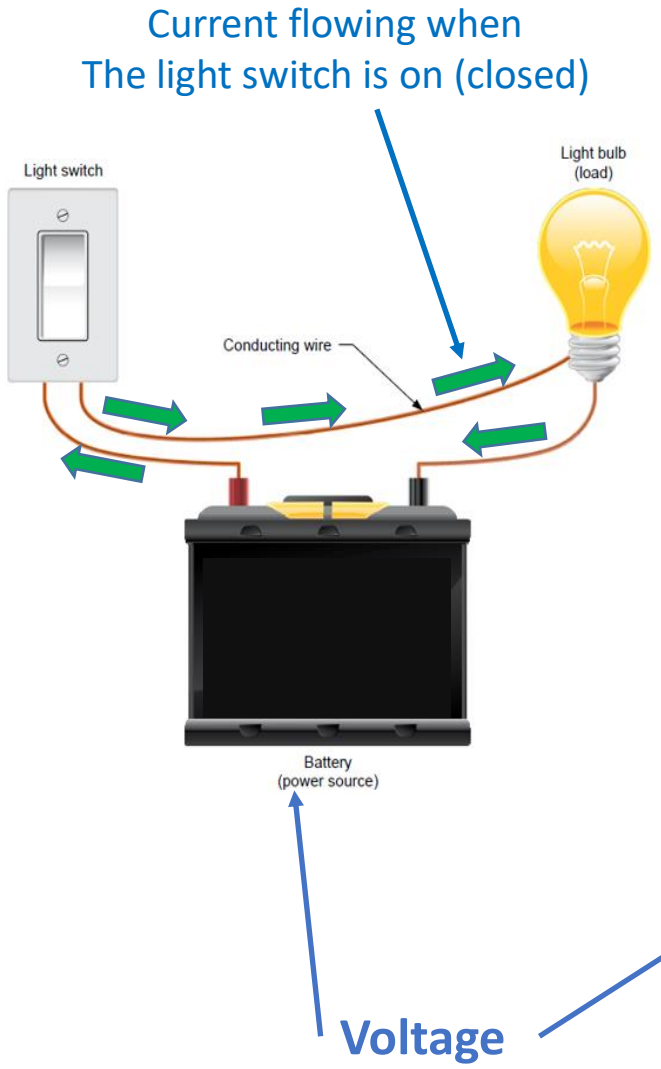
The **load**, in this circuit is the light bulb.

A **switch** for turning the circuit on and off.

Wires (or conductors) that connects the components together, and give a path for current flow.

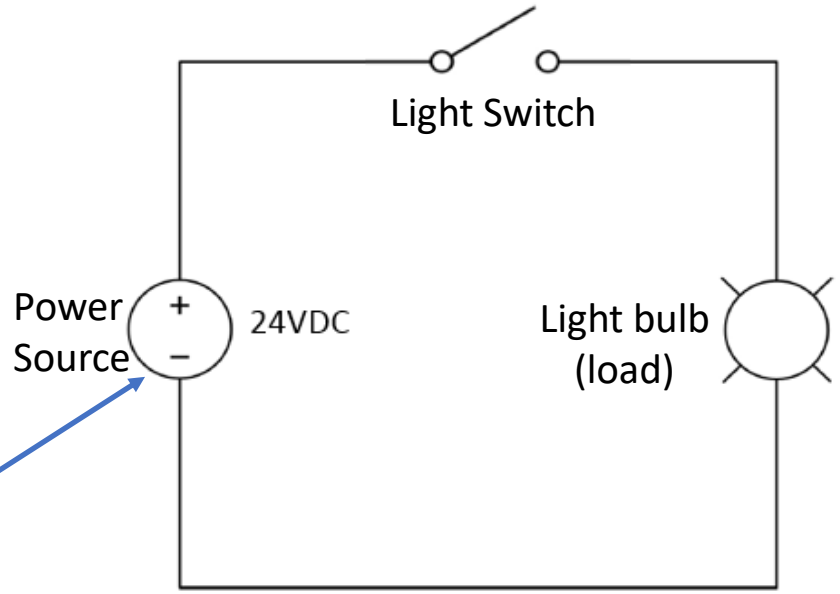
When the switch is turn on (or closed) voltage is applied across the load, and current will flow through the circuit, which should turn on the light bulb.

Electrical Terminology



Physical View of Electrical Circuit

Electrical Circuit Diagram



A few terms that are important that will be expanded on later in the course:

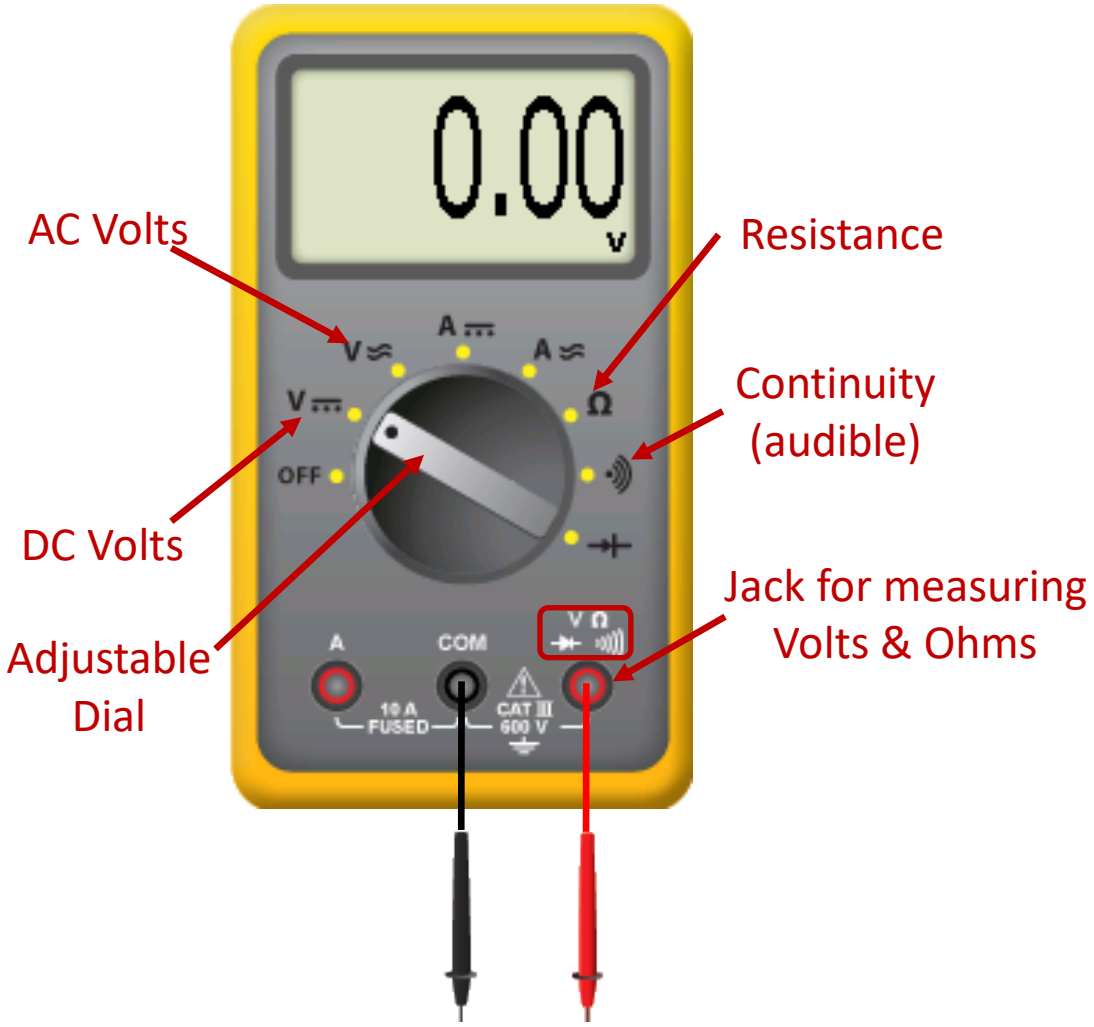
Voltage: This is a force or potential that is put on a circuit to create current flow. It is many times termed EMF, for Electro-Motive Force. The letters "V" or "E" represent voltage. Voltage is measured in the units of Volts.

Current: This is the flow of electrons through the circuit (through the wires and the load). Current is measured Amperes, or Amps for short.

Resistance: This is the opposition to current flow. All loads (lights, coils, heating elements and motors) have a resistance. Switches are usually either zero resistance or infinity resistance. Resistance is measured in Ohms.

This illustration shows the physical components in a circuit, as well as an electrical circuit diagram.

A virtual digital multi-meter for testing:



Since electricity is invisible, we need to use test equipment to measure the different things in an electrical circuit. This example shows a virtual digital multi-meter that is used in Automation Studio, but is also very similar to any actual digital multi-meter.

The focus will be on using the meter to measure voltage and resistance.

The dial in the center of the meter must be in the correct position.
**Warning: never use a meter in a powered circuit, if the dial is on the Resistance or Continuity setting. It can damage your meter.

The two things to measure with a digital multi-meter in this course is:
Voltage – Usually 24Vdc,
Resistance – Open Line, actual resistance

A digital multi-meter used in the lab:

Since electricity is invisible, we need to use test equipment to measure the different things in an electrical circuit. This example shows an Amprobe multi-meter that is used in the South Arkansas CC Advanced Manufacturing Lab.

The focus will be on using the meter to measure voltage and resistance.

The dial in the center of the meter must be in the correct position.
**Warning: never use a meter in a powered circuit, if the dial is on the Resistance or Continuity setting. It can damage your meter.

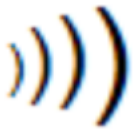
The two things to measure with a digital multi-meter in this course is:
Voltage – Usually 24Vdc
Resistance – Open Line or actual resistance.

Electrical Symbols found on Multimeters

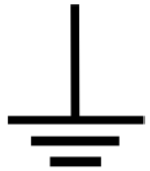
This is a designation on many DMMS to represent AC Volts

This is a designation on many DMMS to represent DC Volts

This is the Omega symbol, which in the electrical field is used to designate Ohms, which is resistance



This is a designation on many Digital Multimeters to represent an audible tone. Primarily to determine if a device has continuity.



This symbol is used to designate earth ground, or equipment ground

The electrical field uses many types of designations and symbols to represent devices and voltages.

This is just a few of the designations and symbols that will be found primarily on multimeters.

Continuity means that a device will allow current to flow. An open contact does not have continuity.

Basics of continuity & resistance

Standard
Toggle Switch

Switch is open
Switch has no continuity
Resistance is infinite resistance

Switch is closed
Switch has continuity
Resistance is zero ohms

Continuity is a term used to explain that current can flow through a device. There is a path for current flow. Either a device has continuity or it does not.

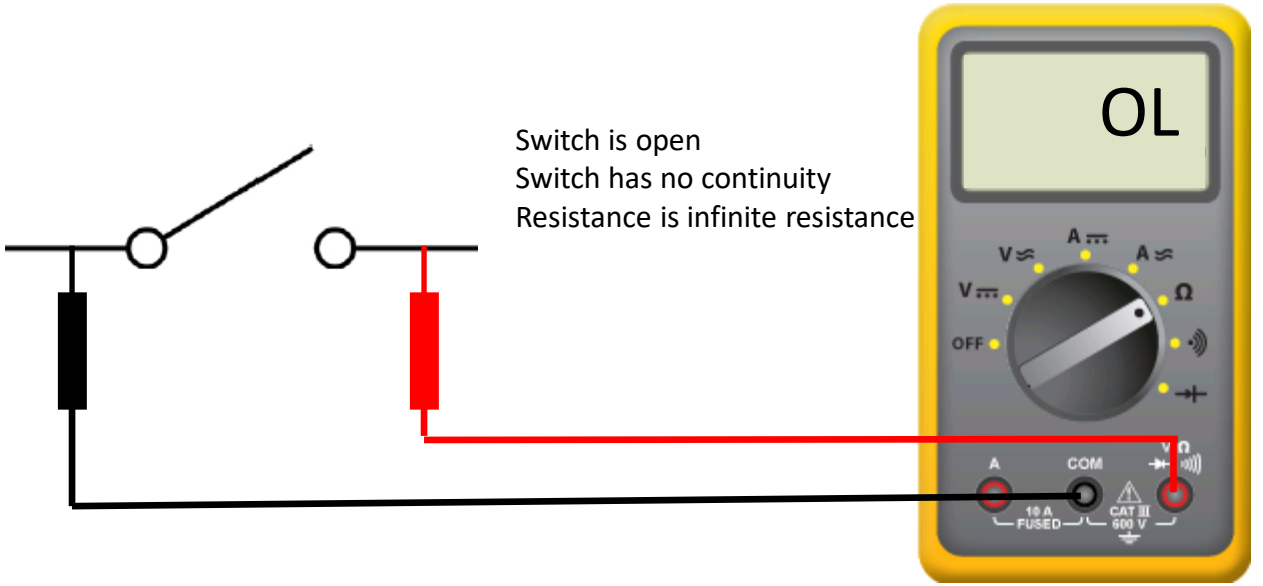
Resistance is the opposition to current flow. Resistance is measured in Ohms. The device used to measure resistance is a Digital Multi-Meter, that is set up to measure resistance.

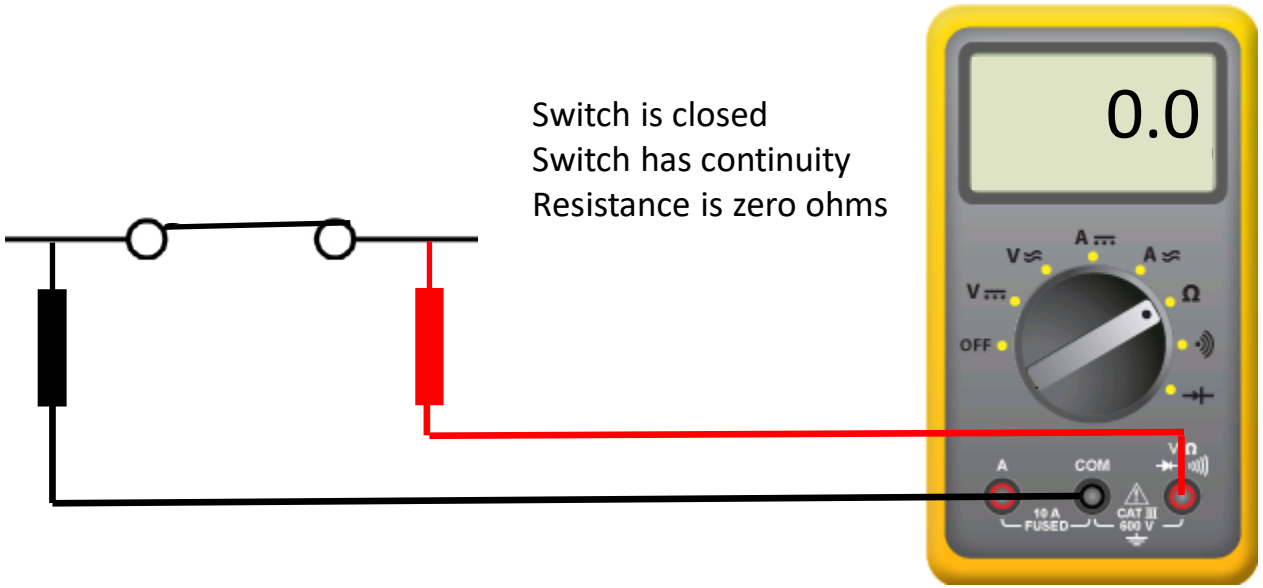
This course will discuss many types of switches. The most basic switch is a toggle switch. The user can toggle the switch on (up position), or off (down position). This is the same as a light switch in your home.

When the light switch is closed, it has continuity, which will allow current to flow, and the light will come on.

When the light switch is open (off), it has no continuity and the light will shut off.

Testing the Continuity of a Switch



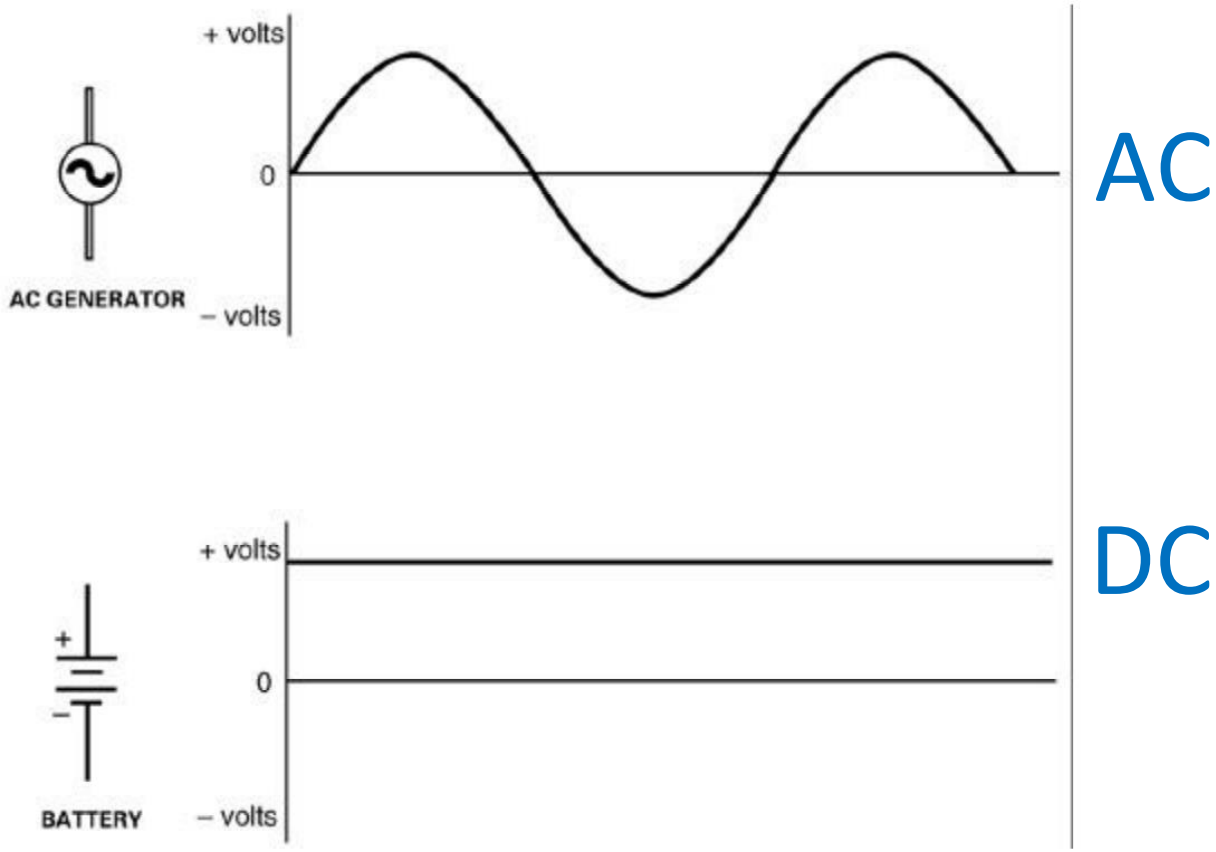


In this illustration An Ohmmeter will be used to measure the resistance of a basic toggle switch. The switch will be either "on" or closed, or it is "off" or open.

In the top image the Ohmmeter is across an open switch. The switch has no continuity and measures infinite resistance. The meter display will show an OL, which means open line. Current will not flow through an open switch.

In the lower image the Ohmmeter is across a closed switch. The switch has continuity and measures zero resistance. Current will flow through a closed switch.

AC power versus DC power:



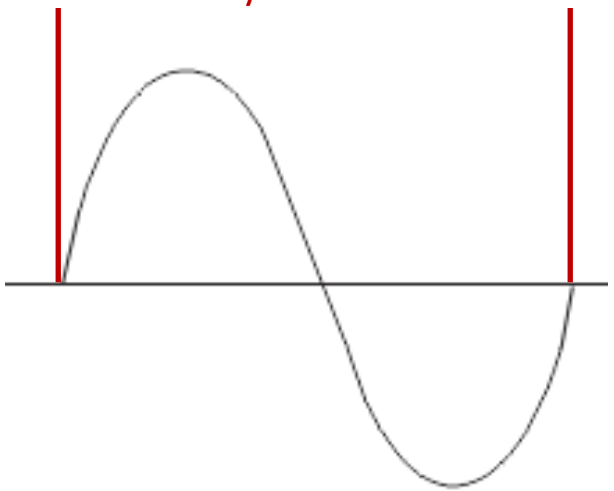
This slide compares the waveforms for both AC and DC power waveforms.

The top graphic is an AC (Alternating Current) waveform, that is many times called a Sine Wave. Notice that it alternates from positive to negative continuously (thus called alternating). AC power is predominately used in residential, commercial and industrial environments.

The lower graphic is DC (Direct Current), which does not alternate, it stays a steady voltage. A flashlight or smoke alarm battery is DC. In an industrial environment, DC will be used to power the control systems of a machine, and will also be used within a variable frequency drive.

We will cover and compare the basics on both DC and AC electricity in the following slides.

AC Single Phase Power



60 hertz means that 60 cycles occur in one second

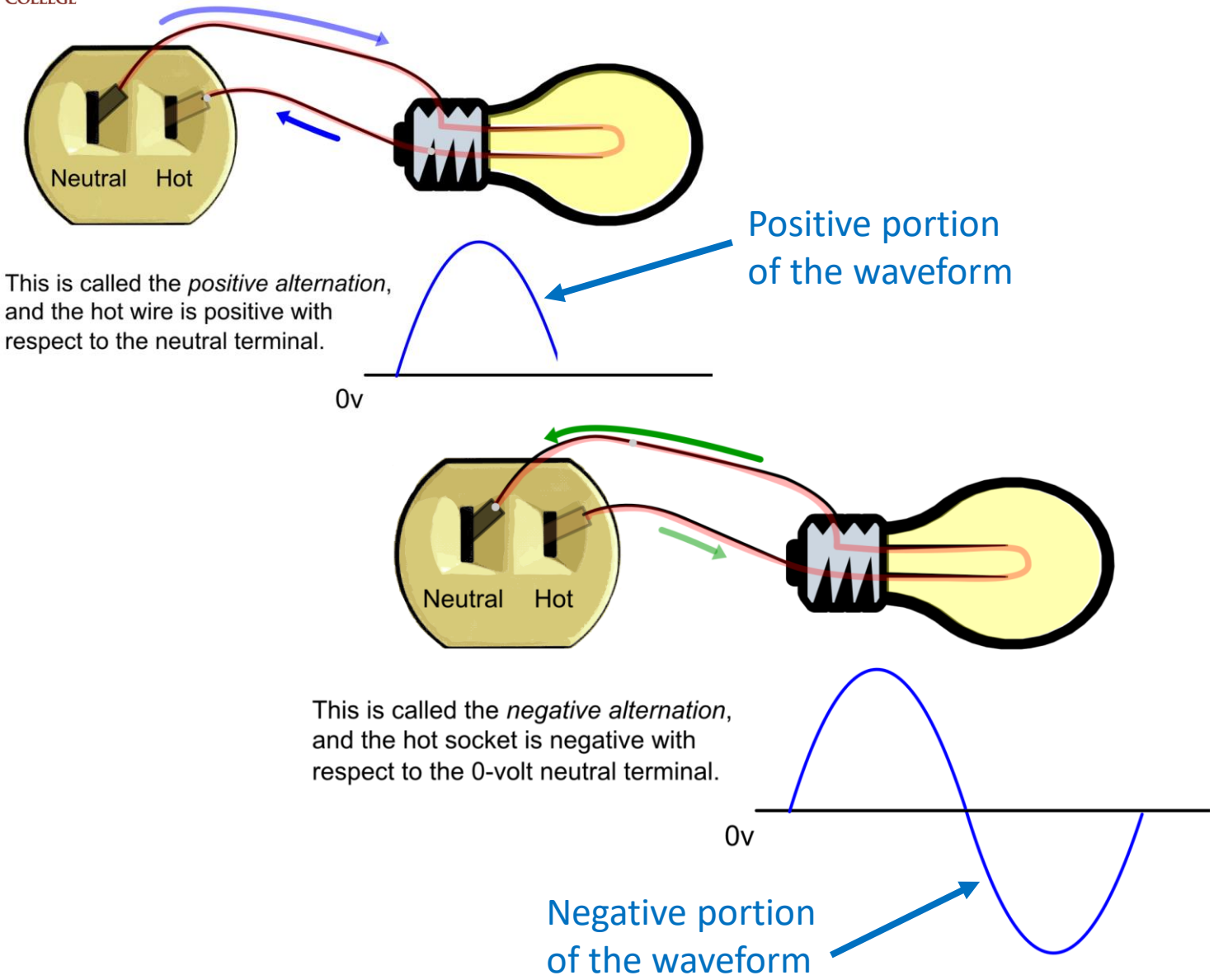
A standard wall outlet
In a home or in industry
is 120Vac, at 60 Hz

The AC sine wave is the waveform a student would see if an oscilloscope was connected to AC power. This waveform is created by a generator at a power company, and is transformed along the way to a useful voltage to power electrical equipment.

This AC waveform is measured in cycle (or Hertz). One AC waveform as shown is a cycle. 60 of these cycle occur in 1 second, which is called 60 hertz. All power companies in the United States generate and distribute AC electricity at 60 Hertz (HZ.) to their customers.

This waveform would also be called single phase. This is the power found on outlets and lighting circuits.

Alternating current flow:



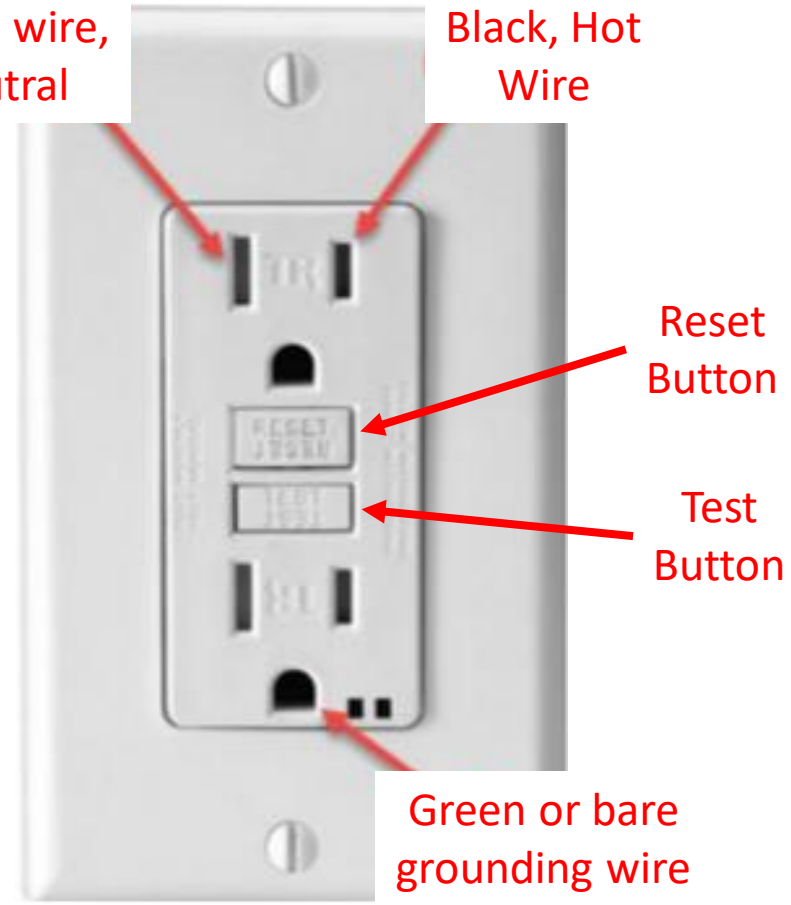
This slide shows a light bulb that is powered with AC (120 VAC) power from a standard residential power outlet.

The current flows in one direction during the positive portion of the AC sine wave. Notice that it flows from the Neutral portion of the plug, through the light, then back to the hot side of the outlet.

The current flows in the other direction on the negative portion of the AC sine wave, thus in the lower portion of the graphic, current flows from the Hot portion of the outlet, through the light, then back to the Neutral side of the outlet.

Realize that this is why they term “Alternating Current” (AC) is used, the current changes direction every half cycle.

GFCI Outlet Wiring



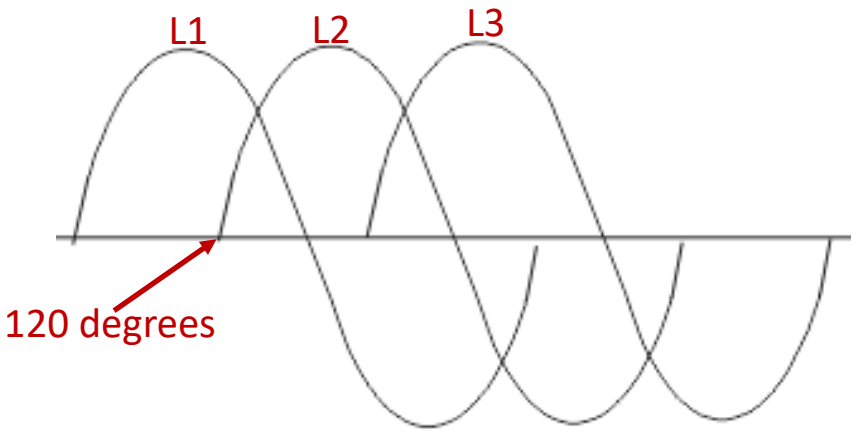
This graphic shows the wiring of a Ground Fault Circuit Interrupter. These devices will be in the form of an outlet, or as a breaker in the power panel. The purpose of these devices is to protect an individual from electrocution by sensing the current difference between the hot and neutral wires. If there is a difference of more than **5mA (which is enough current to electrocute someone),** the device will trip, shutting off the power.
These are required in outside outlets, or in bathrooms; primarily anywhere that there is a lot of moisture.

Notice the wiring is the same as a standard outlet for the hot, neutral and grounding conductor.

The **Test button**, when pushed will create a 5mA difference between the hot wire and the neutral wire, which will shut off the device.

The **Reset button** will power the GFI outlet.

AC Three Phase Power



Three Phase
AC Motor

A three phase power waveform would look like this graphic. Notice that this is made up of three single phase waveforms. There is a 120 degrees phase shift with three phase. This means that 120 degrees into the first sine wave, the next single phase sine wave starts. Then 120 degrees later, the next sine wave starts.

Three phase is more powerful than single phase. This is why most industrial motors are three phase. The three phase motors are smaller than the same horsepower single phase motor.

240Vac three phase is a common motor voltage, as well at 480Vac three phase. Many motors are dual voltage rated, so they could be wired for either 240 Vac or 480 Vac. In most cases the motor is wired for 480 Vac, which will require smaller size power wires to carry the current, thus a lower cost installation.

Direct Current (DC) Sources

12 Vdc Car Battery

Small DC Batteries

24 Vdc Industrial Power Supply

There are typically two types of direct current power sources: Batteries & DC power supplies.

Batteries are manufactured from certain materials that create a DC voltage. Some batteries are rechargeable, and others are disposable.

Larger batteries are found in cars, tow motors and automatic guided vehicles.

Smaller batteries are found in hand tools, smoke detectors and many other small devices.

DC power supplies are devices that take AC electricity and converts it to DC. The most common DC voltage found in industry is 24Vdc. Many control circuits are 24Vdc, which controls machinery.

DC has polarity, so there is a “+” and “-” connections on each DC source.

Alternating Current (AC) Sources

120 Vac outlet

AC electrical disconnect

AC electrical power panel

Alternating Current (AC) is the most used type of electricity in an industrial environment.

AC will be used to run motors, power lights, and power heating elements in a manufacturing environment.

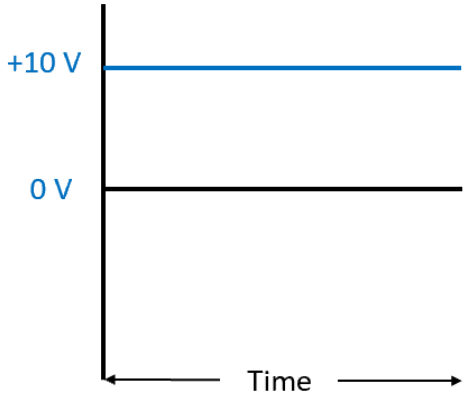
AC power is generated at a power plant and distributed to customers through an electrical distribution network, which is beyond the focus of this course.

Users will get their AC power from a number of sources such as duplex receptacles (outlets), electrical disconnects, and electrical power panels. We will discuss a few more sources in later courses.

AC can also be single phase, or three phase.

In this course the user will be using 24Vac or 120Vac.

DC Basics:



DC stays at a consistent voltage over time, and does not alternate or change direction

Symbol for a DC Power Source

Symbol for a DC Power Source, 2 batteries in series

24 Vdc Power Supply found in most electrical panels

Various Batteries

DC stands for Direct Current, which is typically low voltage type of electricity. The most basic form of DC is a battery.

An important characteristic of DC power is that current only flows in one direction, and it is constant with time, as shown in the top graphic. The primary sources for DC power is batteries and DC power supplies.

Another important characteristic of DC is that I cannot transform it through a transformer. In the following slides, we will discuss AC power, and its advantage of being able to transform to different voltage level.

There are a number of applications for DC power in an industrial environment. Tow motors (lift trucks) is one of our more common applications. The track has a bank of batteries that will run a DC motor. DC is very common on industrial machinery to power the control circuit of a production machine. The most common control voltage is 24 Vdc, which will come from a DC power supply, as shown in the lower graphic.

Practice Question #1

What are the two power sources for DC voltage?

- a. Wall outlet
- b. DC Power Supplies
- c. Batteries
- d. All of the above

The Answer to Practice Question #1

What are the two power sources for DC voltage?

- a. Wall outlet
- b. **DC Power Supplies**
- c. **Batteries**
- d. All of the above

Explanation: The two sources for DC power is batteries and power supplies. Many devices have their own internal power supplies such as variable frequency drives. Incoming AC power is converted to DC power within a VFD. Batteries are used in many industrial applications.

Practice Question #2

What would be the voltage measured on a standard outlet used at home?

- a. 60 VAC
- b. 120 VAC
- c. 120VDC
- d. 208 VAC

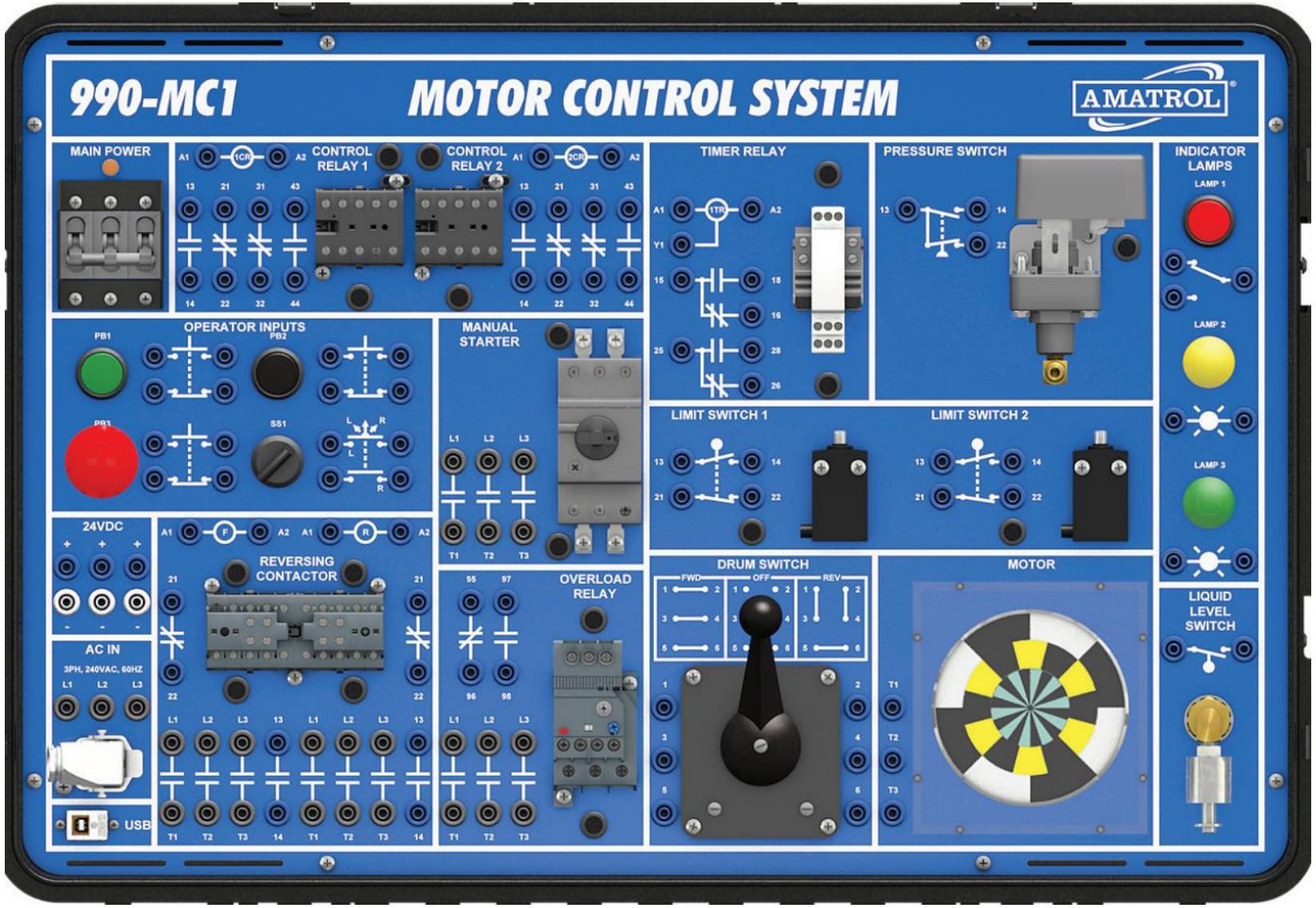
Answer to Practice Question #2

What would be the voltage measured on a standard outlet used at home?

- a. 60 VAC
- b. **120 VAC**
- c. 120VDC
- d. 208 VAC

Explanation: A standard outlet (also called a duplex receptacle) found in your home, office or industrial environment is 120Vac. The outlet shown is also rated at 15 amps.

Motor Control System Training Unit:

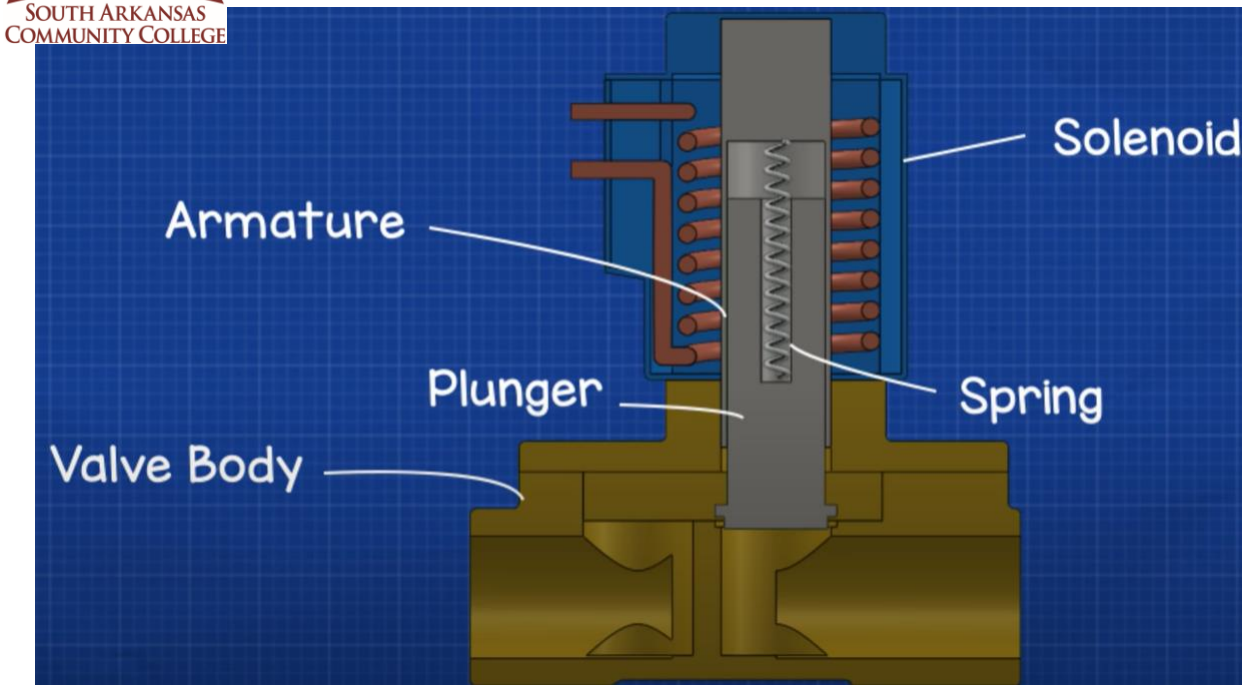


This is the Amatrol Motor Control training unit found in the Advanced Manufacturing lab at South Ark CC. The students will use this training unit to perform their lab exercises and their practical (hands-on) assessments for the course.

This unit is powered with a 208Vac three phase power feed, which is used to power a 24 Vdc power supply on the unit. This course will focus on using only the 24 Vdc power.

It is important when working in the lab to wear safety glasses even if the circuit is not powered.

Solenoid Coil:



The lower left graphic shows the symbol for a solenoid coil on an electrical print.

This example shows a 2-way valve (2 ports). It is a valve that opens or closes off the flow of air, fluid, gas, etc.

The most important thing about these valves is that they have 2 parts: The valve (spring and plunger) that is actuated by the magnetic force of an electric solenoid. This type is termed an ASCO (manufacturer), red hat, due to the red cap. The cap is removed with a screwdriver, then the coil can be removed. If the device is on, you will feel the magnetism with a screwdriver. Sometimes the coil is bad (it opens), or the plunger sticks and must be replaced.

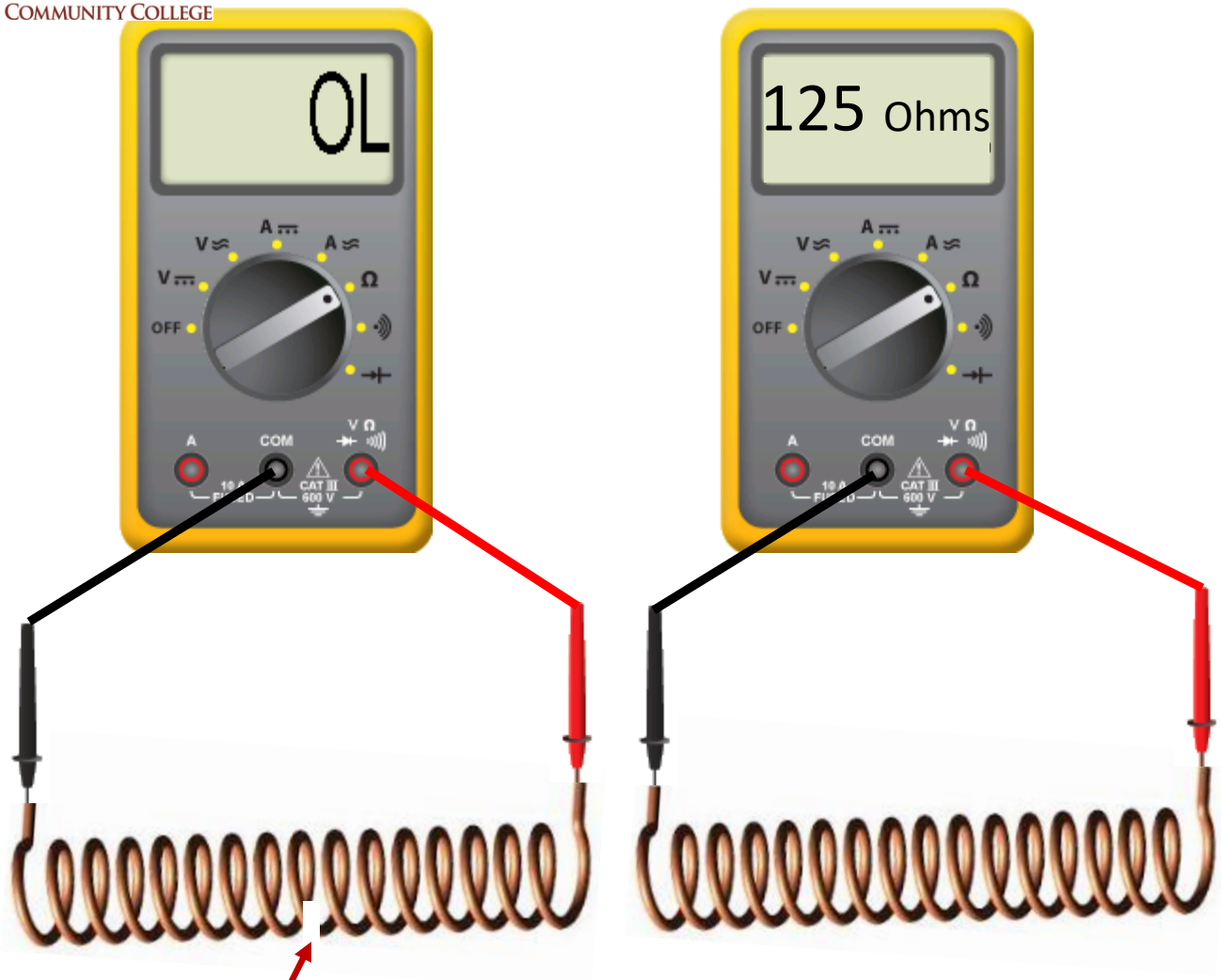
An important thing to remember is that if the coil is 120Vac, is removed from the valve with power still on, a screwdriver must be inserted into the opening in the coil to keep the coil from burning up. No need to do this with a 24Vdc coil.

Electrical Symbol for a Solenoid Coil

Solenoid Coil

Solenoid Valve

Checking the coil out of circuit:



Coil is open, so it will display OL for Open Line

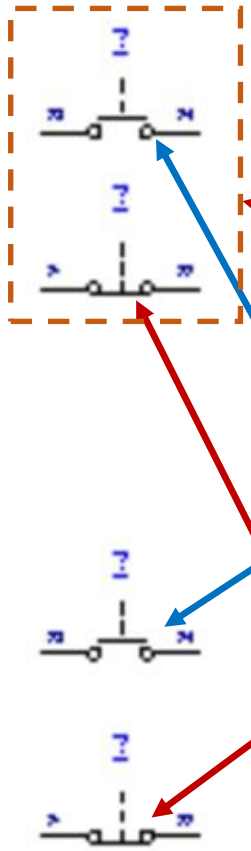
To verify that a solenoid coil is good, the user can measure the resistance when it is not connected in a circuit.
If it is out of the circuit, and an ohmmeter (digital multi-meter on the resistance scale) is put across the coil, the coil is good if it reads a resistance. If it reads a resistance, it also has continuity.

If the meter reads OL, which means Open Line, the coil is bad and must be replaced.

Coils do not typically short out, they open due to overcurrent. There is also a possibility that the insulation on the wire breaks down and the solenoid coil wire could short to ground.

Pushbutton Contacts:

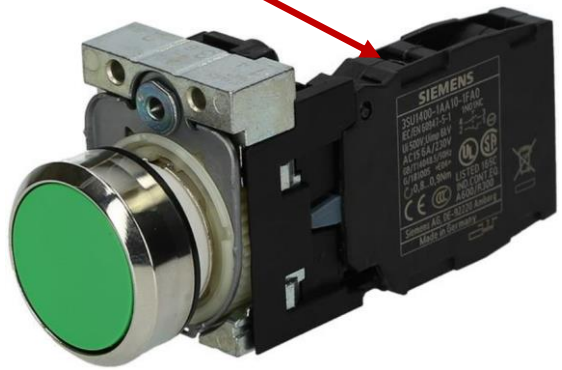
This slide shows a pushbutton, and the contacts attached to the pushbutton (pushbutton contacts). The top graphic shows a pushbutton assembly (pushbutton operator, and the contact block).
The lower graphic shows what would be termed a start/stop pushbutton station (has both a start and stop pushbutton). Each pushbutton has a normally open and a normally closed contact connected to it. This will be illustrated in the Automation Studio software, and also on the Amatrol Motor Control trainer.



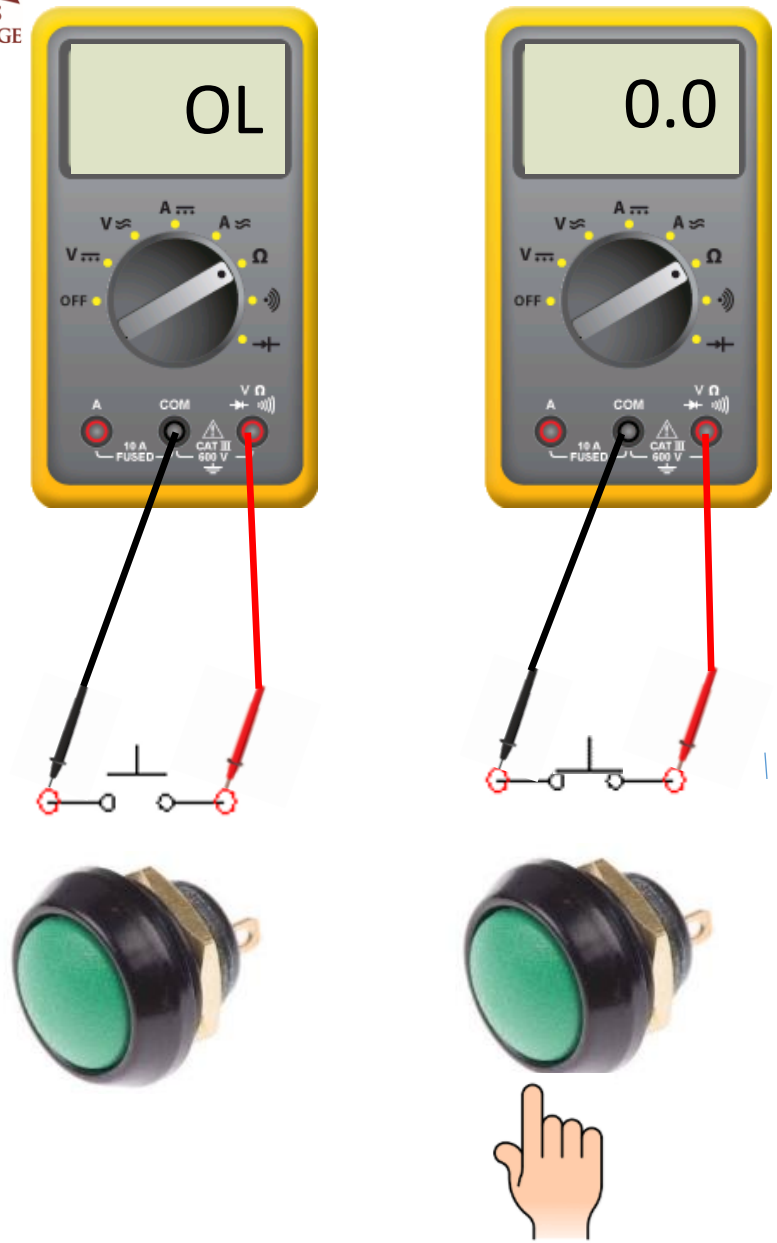
Pushbutton Contact Block

Normally Open Contacts

Normally Closed Contacts



Testing a Normally-open Pushbutton:



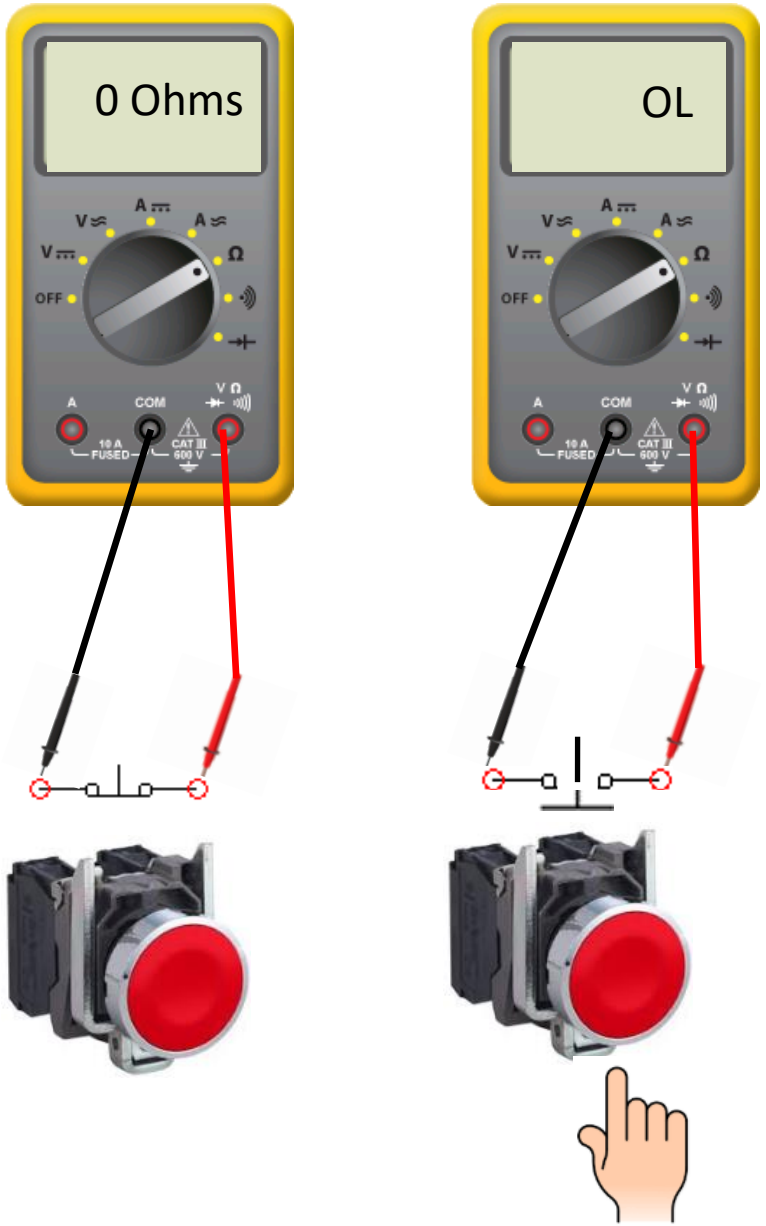
Many times a user must test a Normally-open pushbutton contact when it is out of the circuit, to determine if it is faulty.

The diagram at the left shows a Normally-open (N.O. for short) pushbutton. The resistance should be OL (open line), which is also infinity ohms.

If the pushbutton is pushed, as shown in the right diagram, the switch is now closed, which should measure 0 ohms.

To remove the pushbutton from a circuit, power down the circuit (remove power), then take a wire off of one of the two terminals of the pushbutton, then put the Ohmmeter across the switch terminals.

Testing a Normally-closed Pushbutton:



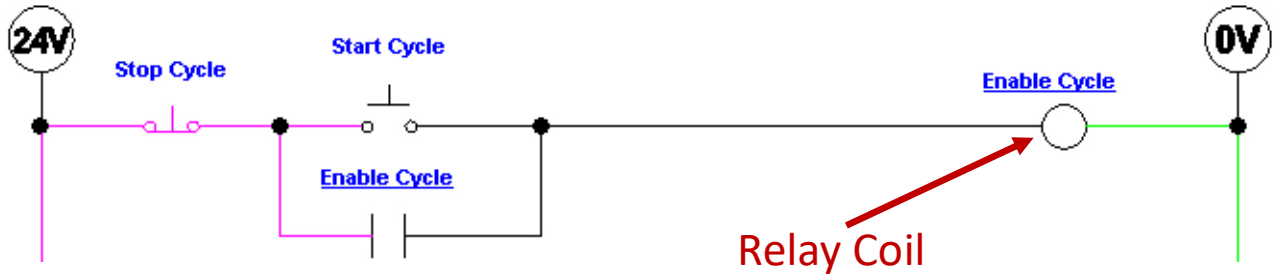
Many times a user must test a Normally-closed pushbutton contact when it is out of the circuit, to determine if it is faulty.

The diagram at the left shows a Normally-closed (N.C. for short) pushbutton. The resistance should be 0 ohms.

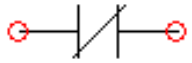
If the pushbutton is pushed, as shown in the right diagram, the switch is now open, which should measure a very high resistance, which should be an open line.

To remove the pushbutton from a circuit, power down the circuit (remove power), then take a wire off of one of the two terminals of the pushbutton, then put the Ohmmeter across the switch terminals.

Relays:



N.O. Relay Contact



N.C. Relay Contact

Industrial IEC Relay

Industrial Ice Cube Relays

This slide shows a basic the symbols and actual devices for an electro-mechanical relay. A relay is used as a logic device in a ladder logic circuit. The relay typically has Normally Open (N.O.) contacts that has no continuity in it's deactivated state. It also may have Normally Closed (N.C.) contacts that should measure 0 ohms (full continuity) in it's deactivated state.

When the relay coil pulls in (gets powered), the contacts change state. The N.O. contact now will have full continuity, and the N.C. contact will open.

The contacts of a relay will be rated at 10 amps or less. Most contacts are rated for at least 300 volts, since the maximum control voltage by law is 250 volts.

These relay coils may be rated at either 24Vdc or 120Vac for an industrial application.

The HVAC world many times use 24Vac coils.

Practice Question #3

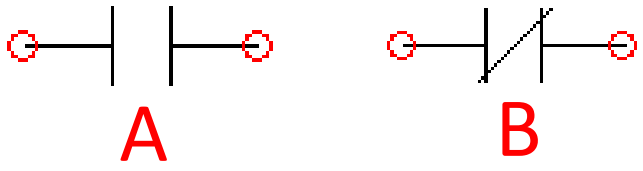
A

B

The symbol marked with a “B” would be a:

- a. Normally-open relay contact
- b. Normally-closed relay contact
- c. Relay coil

Answer to Practice Question #3

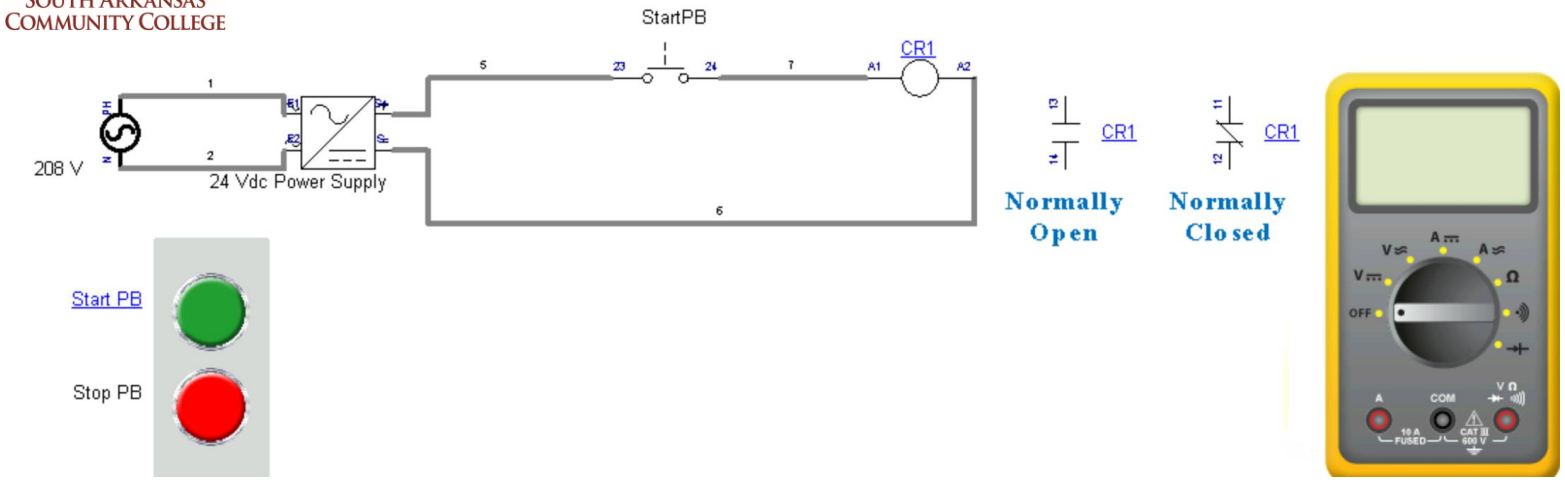


The symbol marked with a “B” would be a:

- a. Normally-open relay contact
- b. **Normally-closed relay contact**
- c. Relay coil

Explanation: The electrical symbol marked with an “A” is a normally-open relay contact. The electrical symbol marked with a “B” is a normally-closed relay contact.

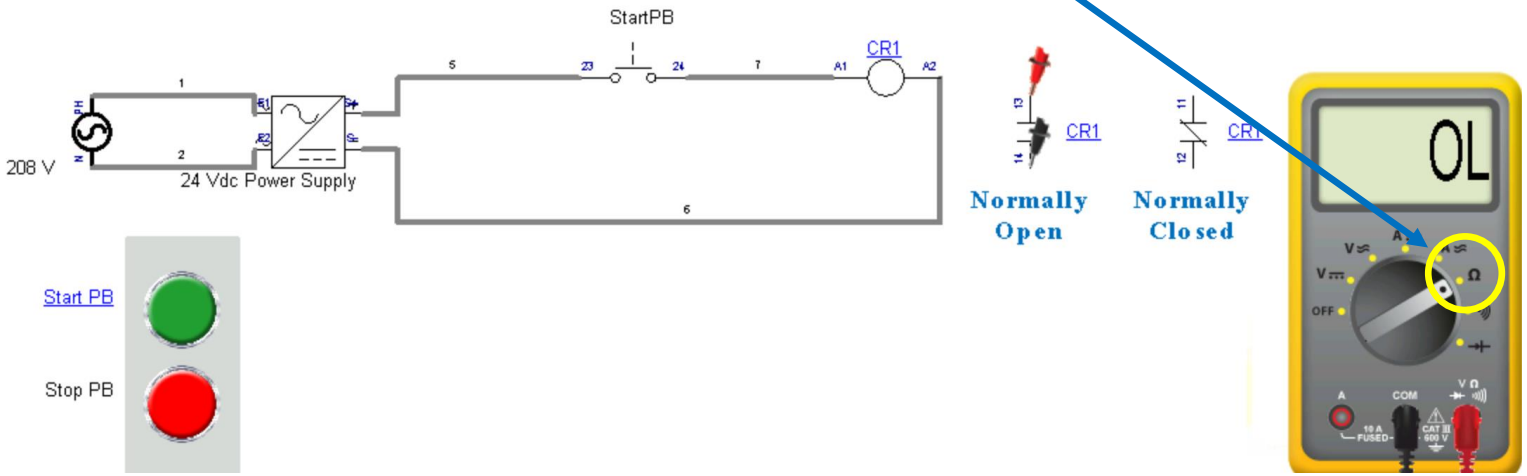
Measuring relay contact resistance 1:



It is important to understand how the Normally-Open (N.O.) and Normally-closed (N.C.) contacts work on a basic relay.

The top graphic shows a 24Vdc power supply powering a circuit with a N.O. pushbutton contact in series with a relay coil (CR1). To the right of the coil is a N.O. and N.C. relay contact.

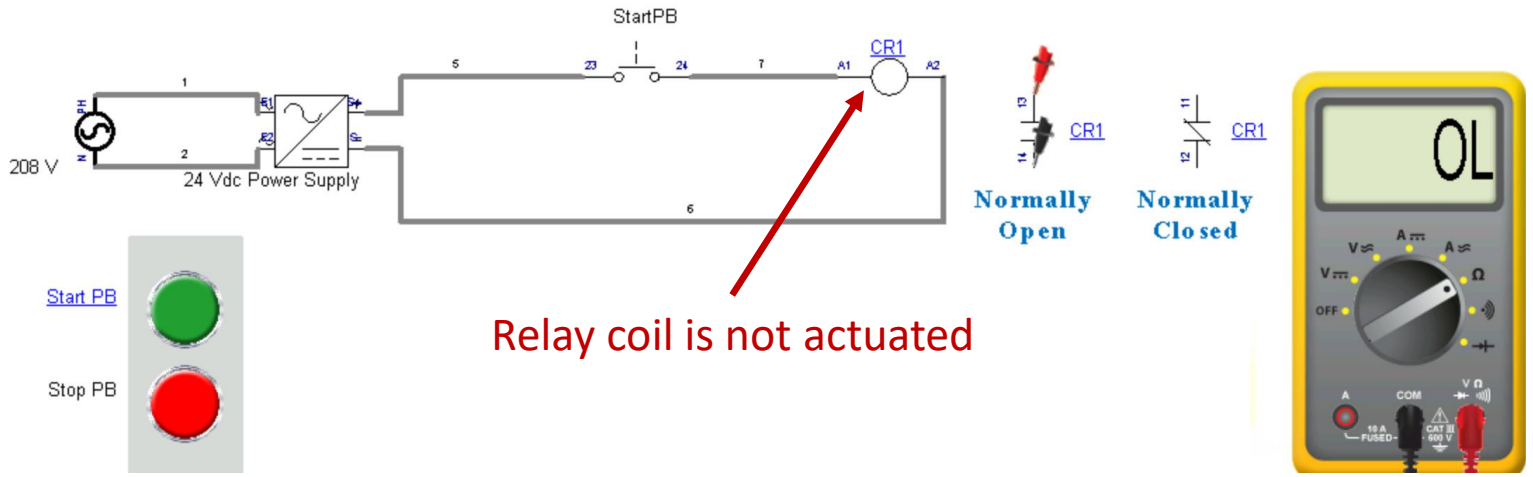
The resistance range marked with an Omega symbol **Ω**

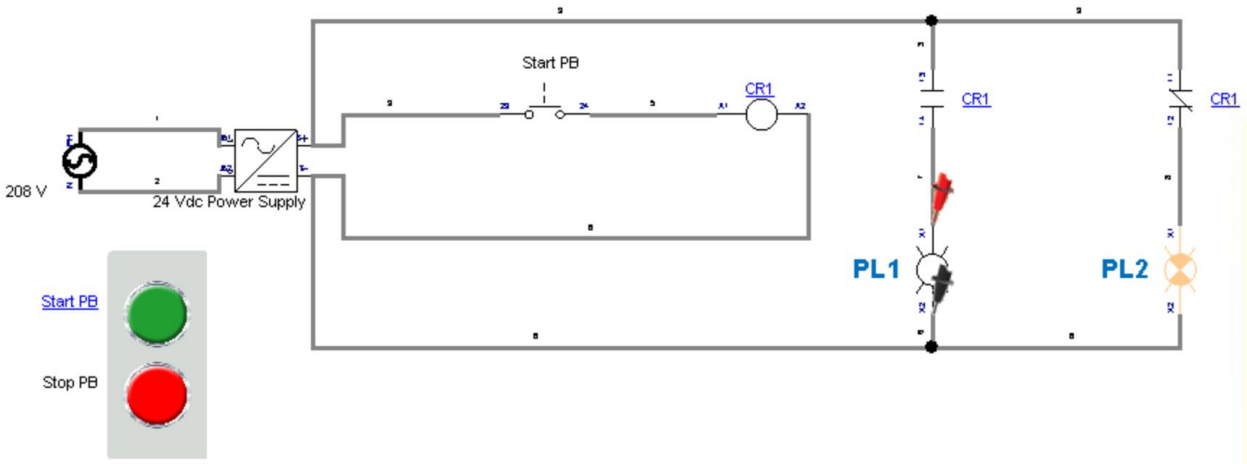


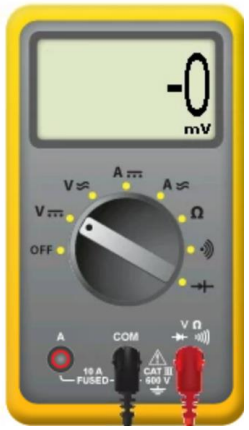
The lower graphic shows a multimeter, that is being used as an ohmmeter to measure the resistance of the relay contacts.

Notice the dial position on the multimeter is on the Omega symbol, which means resistance. The multimeter probes are put across the N.O. contact to monitor the resistance. OL on the multimeter display means Open Line, or infinite resistance, which will not allow current to flow.

Operation of Normally-Open Relay Contacts 1:



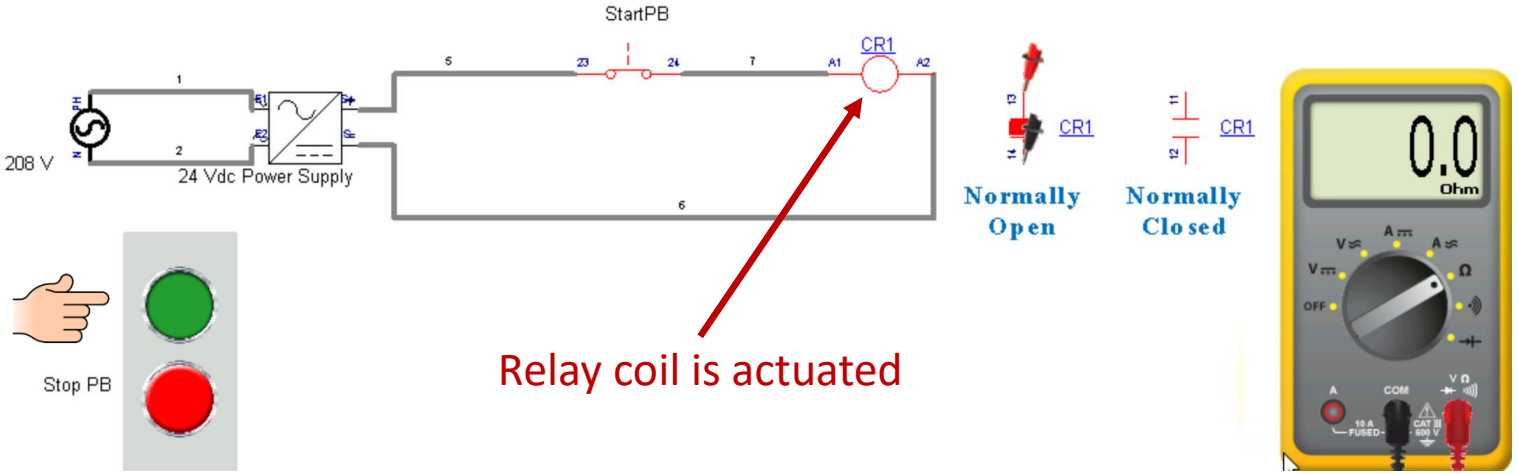


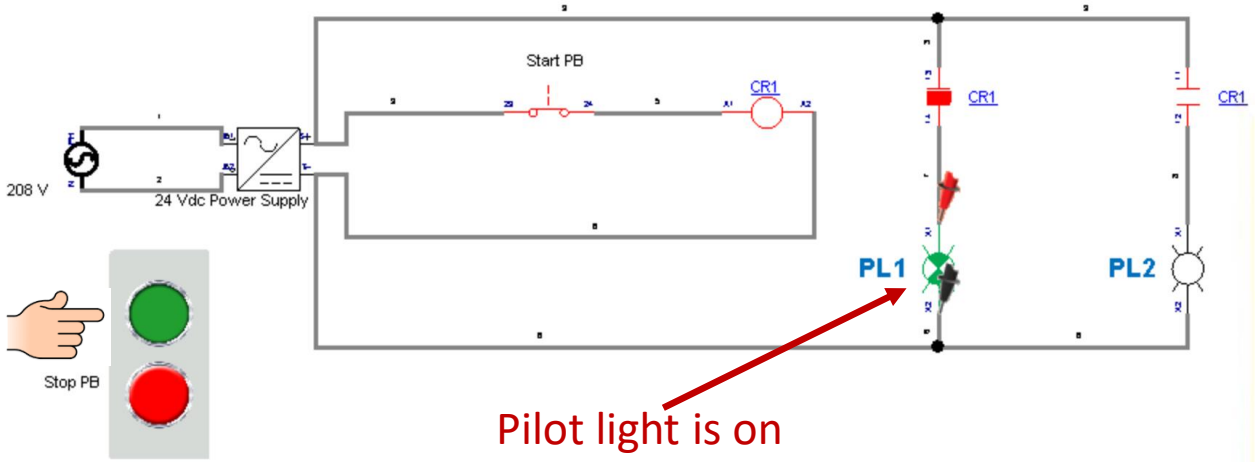


The top graphic shows that the Normally-Open relay contact measures an open line (OL) resistance, which is infinity ohms. This means that current cannot flow through this contact. Notice that the relay coil is not actuated, which means the StartPB is not pushed (actuated).

In the lower graphic, the circuit shows the N.O. relay contact in series with PL1. Since the contact is open, no current will flow to the pilot light, thus there will be no voltage across the pilot light, and it will be off.

Operation of Normally-Open Relay Contacts 2:

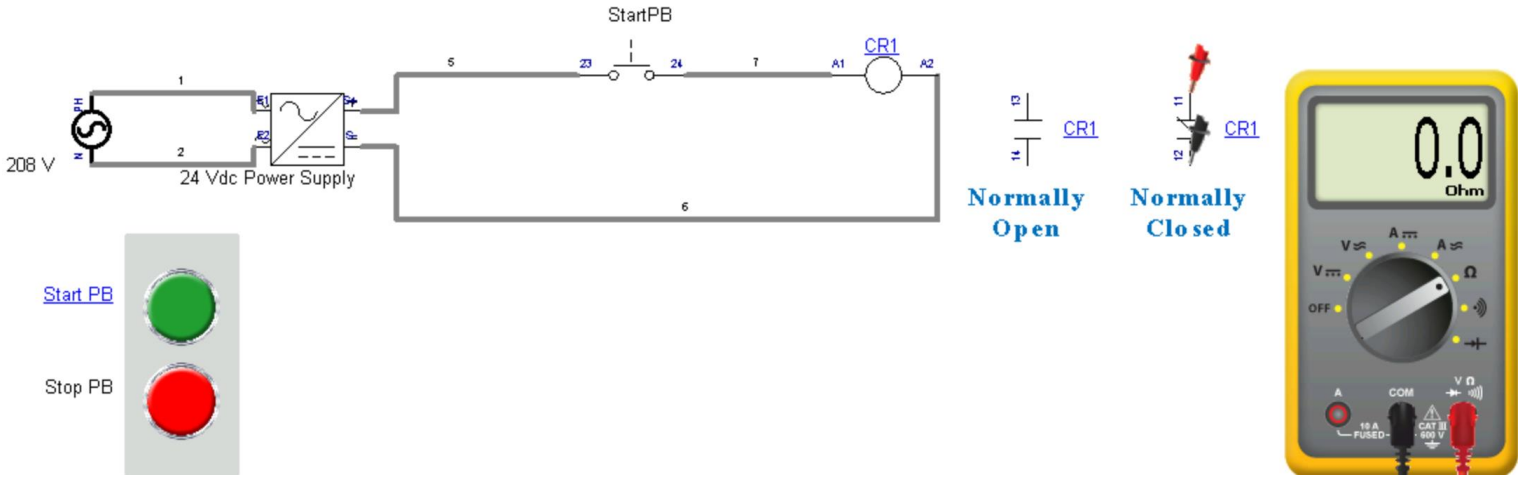


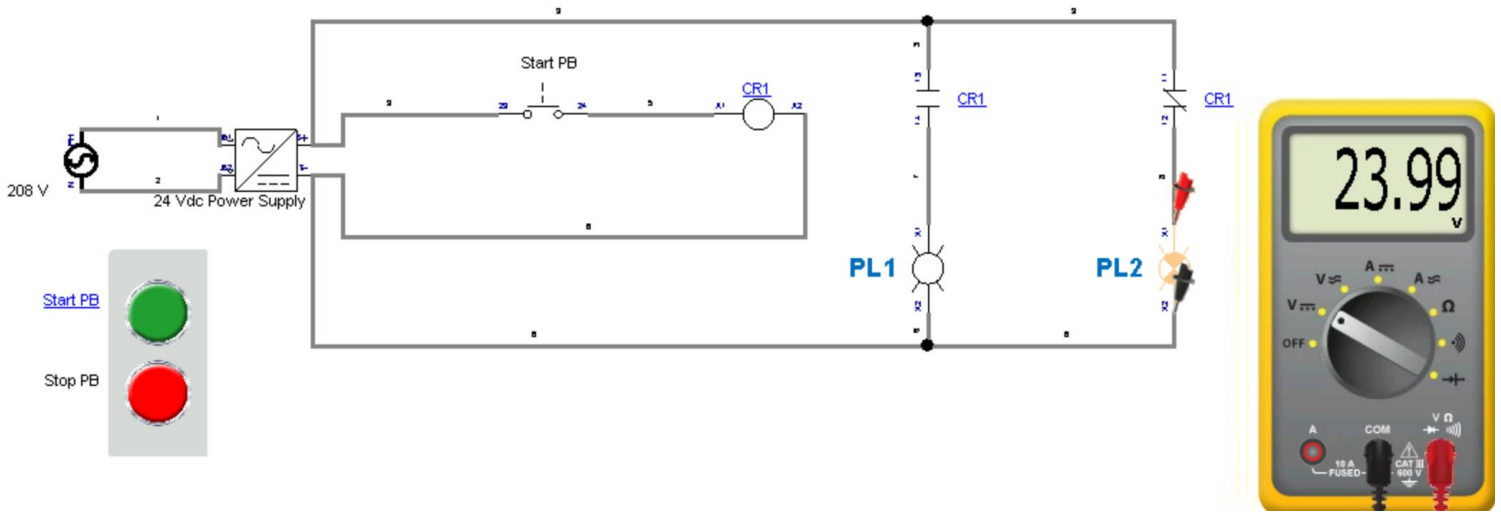


The top graphic shows that the Normally-Open relay contact measures zero resistance. This means that current can flow through this contact. Notice that the relay coil is actuated, which means the StartPB is pushed (actuated).

In the lower graphic, the circuit shows the N.O. relay contact in series with PL1. Since the contact is closed, current will flow to the pilot light, thus there will be approximately 24 Vdc measured across the pilot light, and it will be on.

Operation of Normally-Closed Relay Contacts 1:

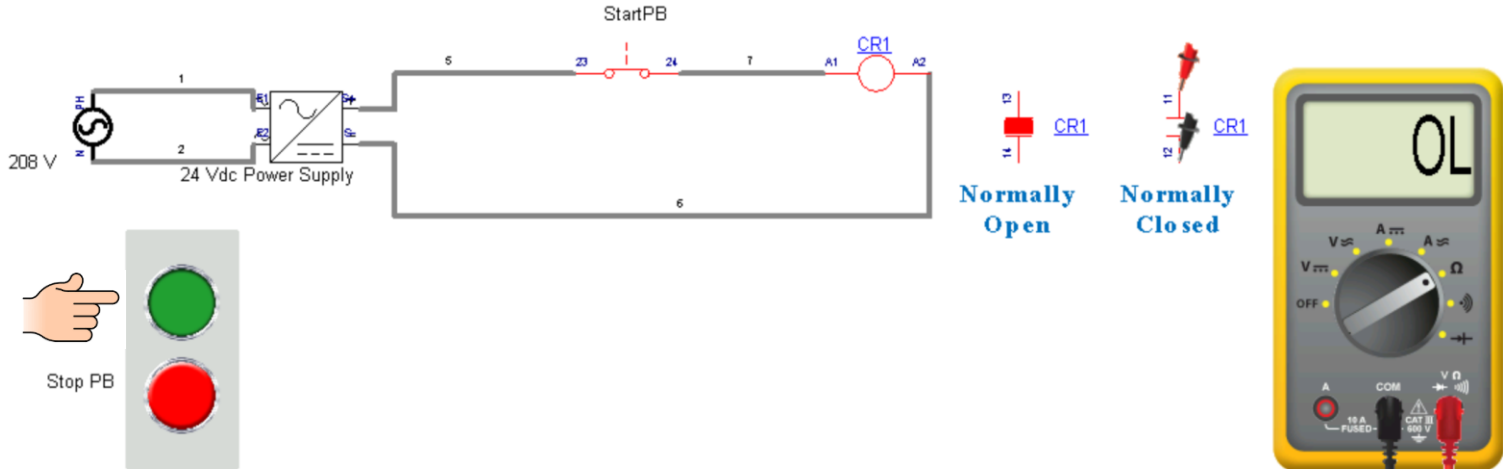


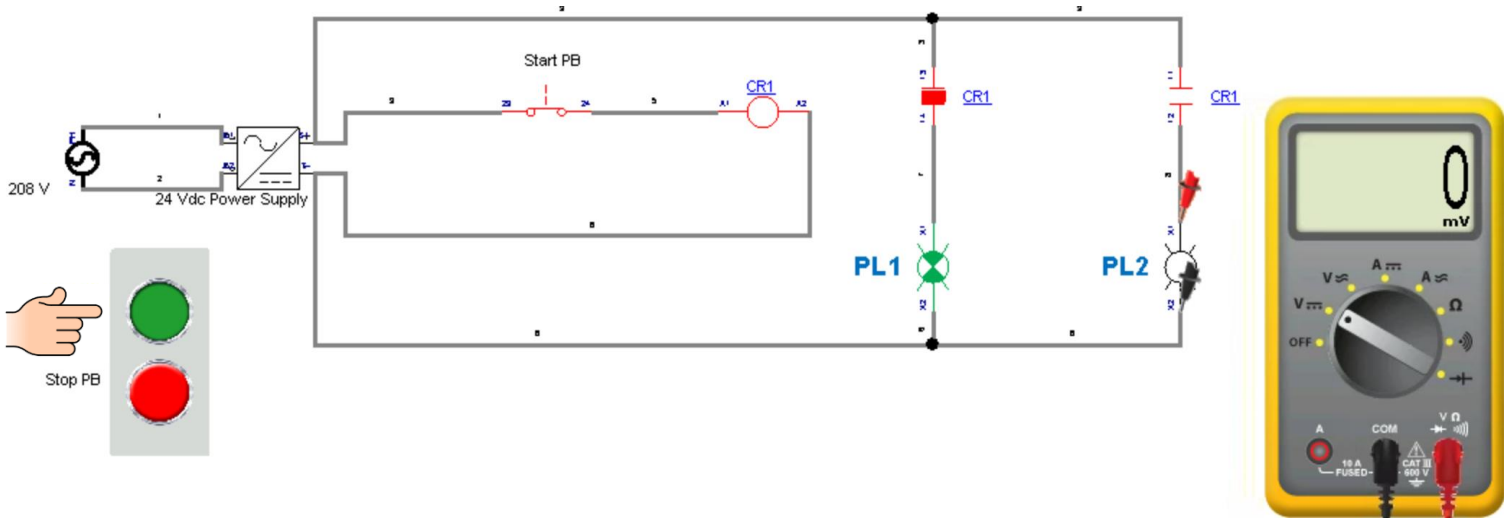


The top graphic shows that the Normally-Closed relay contact measures zero resistance. This means that current can flow through this contact. Notice that the relay coil is not actuated, which means the StartPB is not pushed (actuated).

In the lower graphic, the circuit shows the N.C. relay contact in series with PL2. Since the contact is closed, current will flow to the pilot light, thus there will be approximately 24 Vdc measured across the pilot light, and it will be on.

Operation of Normally-Closed Relay Contacts 2:

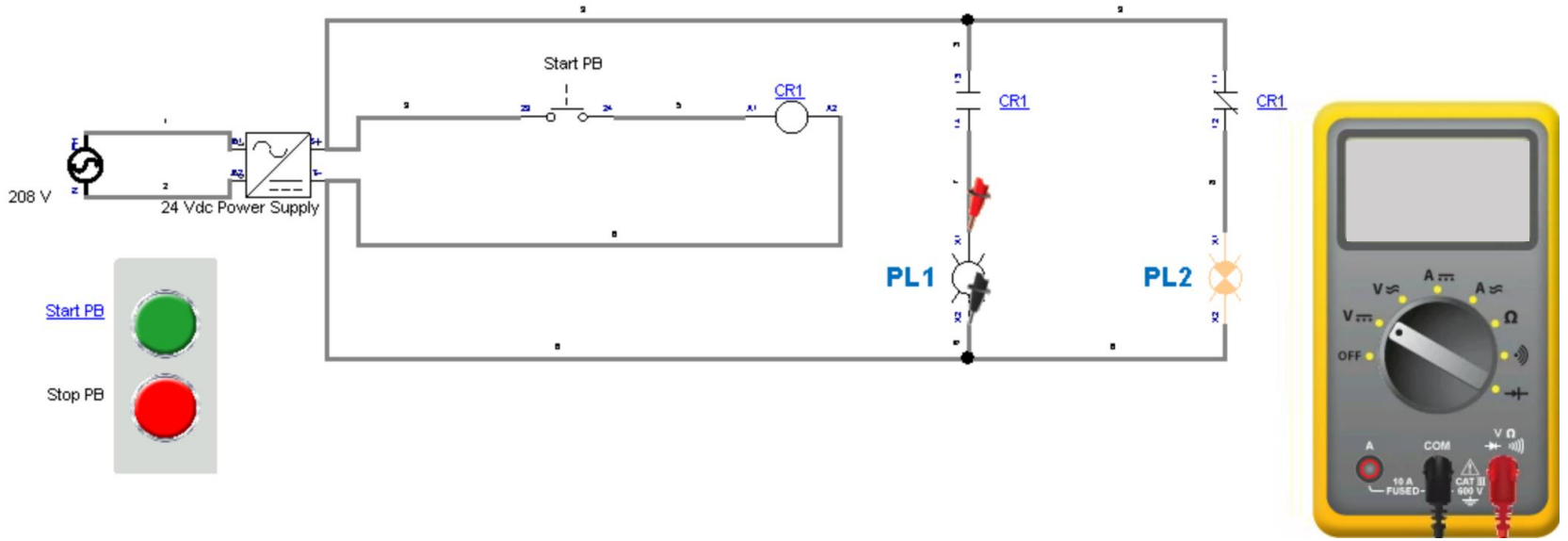




The top graphic shows that the Normally-Closed relay contact measures Open Line (OL), which is infinite resistance. This means that current cannot flow through this contact. Notice that the relay coil is actuated, which means the StartPB is pushed (actuated).

In the lower graphic, the circuit shows the N.C. relay contact in series with PL2. Since the contact is open (due to CR1 relay coil being energized), current will not flow to the pilot light, thus there will be no voltage measured across the pilot light, and it will be off.

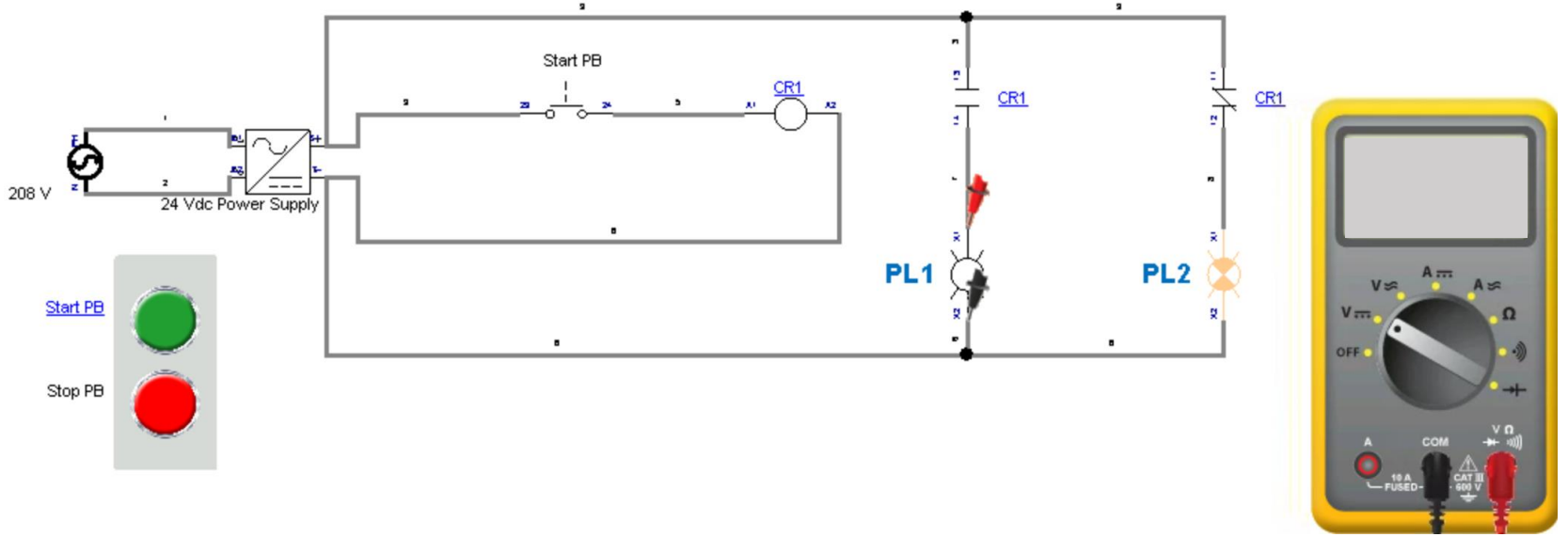
Practice Question #4



What should the voltmeter read in the above circuit?

- a. 24Vdc
- b. 0 V
- c. 24 Vac
- OL

Answer to Practice Question #4

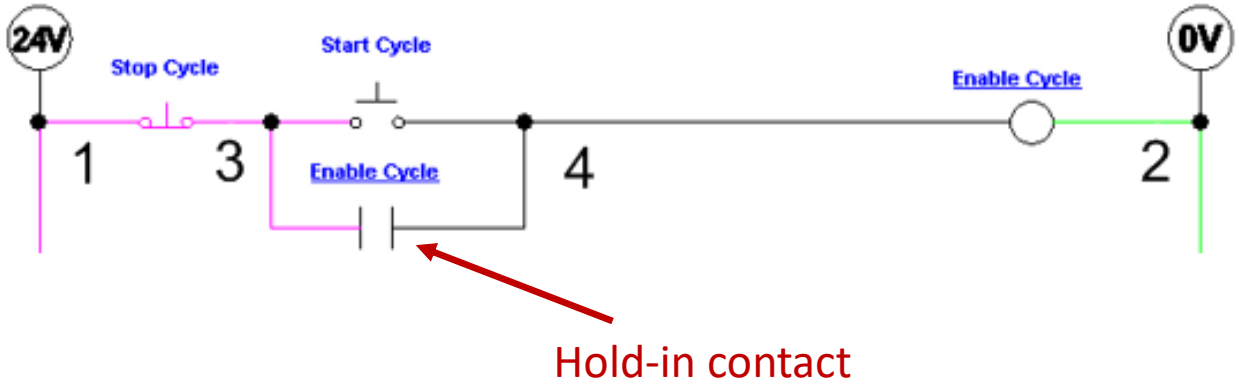


What should the voltmeter read in the above circuit?

- a. 24Vdc
- b. **0 V**
- c. 24 Vac
- OL

Explanation: The voltmeter is measuring the voltage across PL1. Since the N.O. contact is controlling the current to PL1, and the contact is open, due the relay coil not being actuated, there will be no voltage drop across PL1.

Relays used in a Start/Stop circuit:

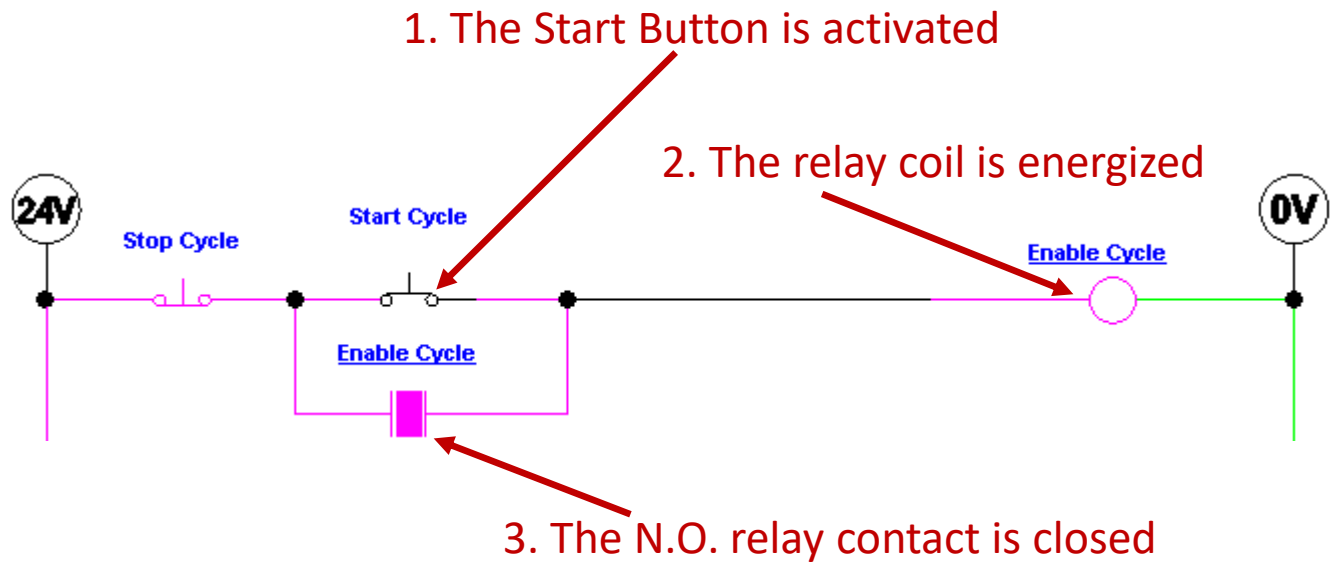


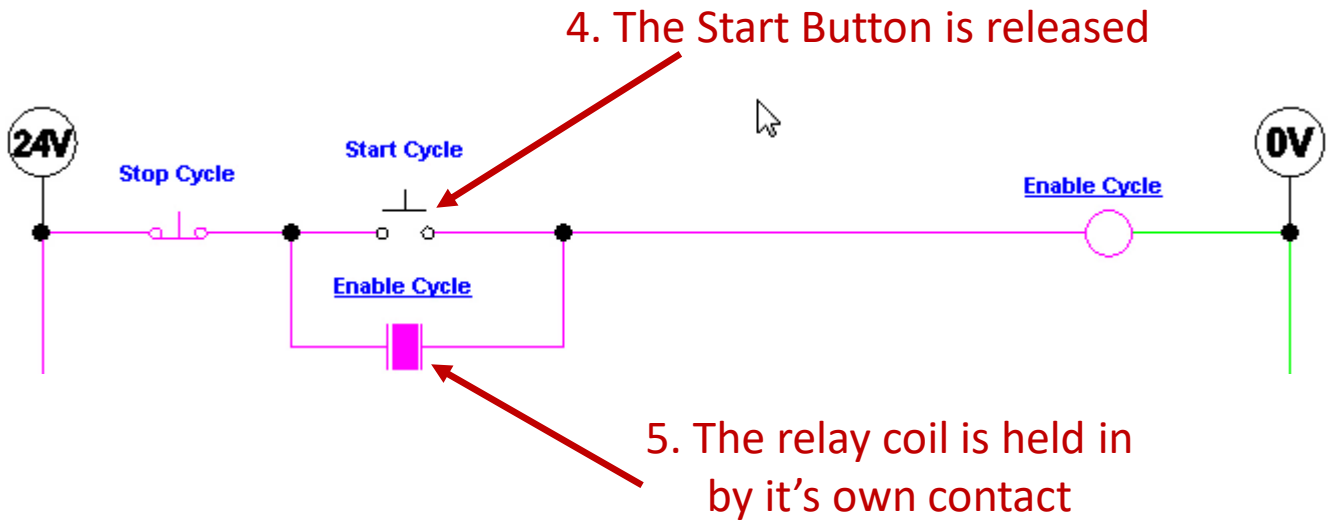
This circuit shows a relay (Enable_Cycle) that is used in a Start/Stop configuration, with a hold-in contact used from the relay. The purpose of the hold-in contact is that when the start button is pushed, the relay coil is energized, which closes the hold-in contact, then when the start button is released, the relay coil remains energized.

Pressing the stop button will shut off power to the relay coil, which will open the hold-in contact.

This is a common configuration in both relay circuits, and motor control circuits.

The Start/Stop hold-in circuit:



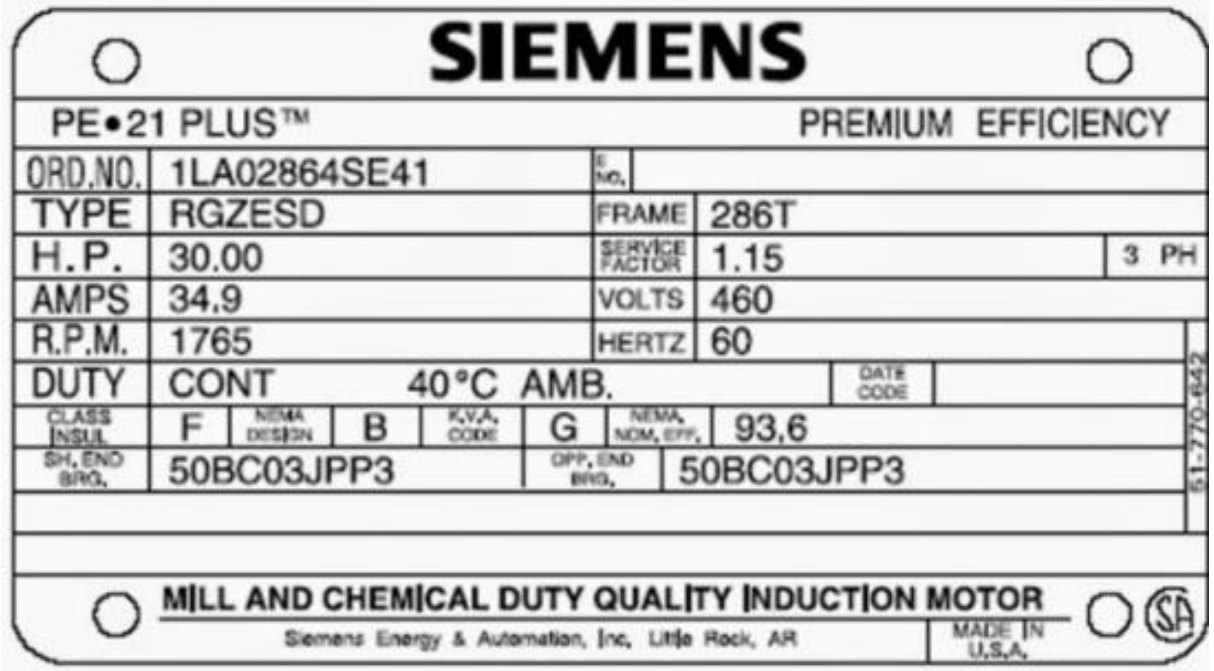


This slide shows the how a start/stop hold-in circuit works. The intent is that when the Start Cycle button is pressed, the Enable Cycle relay coil is energized, and when the Start Cycle button is released, the relay coil remains energized.

To make this work, a Normally Open relay contact must be wired in parallel to the Start Cycle pushbutton. When the relay coil is energized, it closes the N.O. contact as shown in step 3 of this graphic. When the Start Cycle is released, the Enable Cycle relay remains energized.

The way to shut off the Enable Cycle relay is to press the Stop Cycle pushbutton.

AC Electric Motor and Motor Nameplate



AC electric motors are very common in the industrial or process industries. Many of the motors are powered with three phase electricity. Common 3 phase motor voltages are 240 Vac three phase, and 480 Vac three phase. The higher voltage requires smaller wires to carry the current, so most of the time, motors are wired for 480 Vac three phase.

This diagram shows a three phase motor in the lower graphic, and the nameplate on the motor in the upper graphic. A few of the very important parameters on the nameplate are:

1. HP – Horsepower, which is the mechanical power the motor can put out to turn a load. This example shows a 30 HP motor
2. Volts – Rated voltage, in this case is 460 Vac, 3 phase
3. RPM – Revolutions per minute, or the motor speed. In this example is 1765 rpm.

It is important that only qualified electrical maintenance personnel install and maintain these electric motors.

This completes this Instructional Document

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